Understanding the Relationships Between Lightning, Cloud Microphysics, and Airborne Radar-Derived Storm Structure During Hurricane Karl

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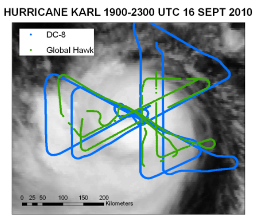
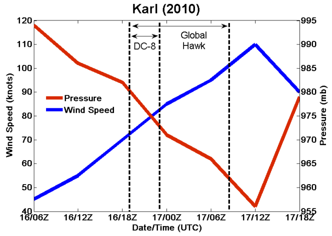
INTRODUCTION AND OBJECTIVES

The relationships between lightning, cloud microphysics, and tropical cyclone (TC) storm structure are being examined using data gathered from flights into rapidly intensifying Hurricane Karl (see figures) during NASA's GRIP experiment.

Objective: Develop a better understanding of the physical properties within electrified and non-electrified regions of a rapidly intensifying TC.

An improved understanding of the occurrence/absence of lightning in TCs may help us understand what information the lightning data are conveying about the storm. This knowledge will be useful for real-time intensity forecast applications as well as future assimilation of lightning data into numerical models.





GRIP DATA COLLABORATION

DC-8	Global Hawk
Airborne Precipitation Radar (APR-2)	Lightning Instrument Package (LIP)
Cloud microphysics probes (CDP, CAS, CIP/PIP)	High Altitude MMIC Sounding Radiometer (HAMSR)
Meteorological Measurement System (MMS)	High Altitude Imaging Wind & Rain Profiler (HIWRAP)

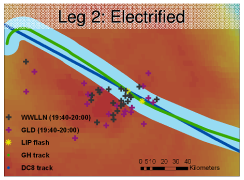
Additional lightning datasets were used to supplement the LIP:

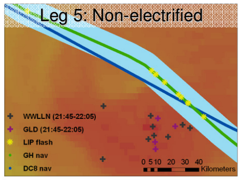
- Vaisala Global Lightning Dataset (GLD360)
- World Wide Lightning Location Network (WWLLN)

METHODOLOGY

The DC-8 and GH made five coordinated, straight line passes (flight legs) through Karl. LIP, WWLLN, and GLD360 lightning data were used to classify flight legs as electrified or non-electrified. We analyzed microwave, satellite, and radar imagery to assess regions of deep convection sampled along each leg. Then, we created time series plots to evaluate the evolution of meteorological and microphysical parameters within the inner core of Karl.

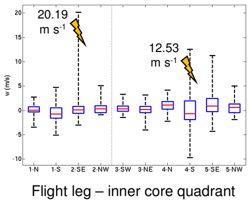
ELECTRIFIED VS. NON-ELECTRIFIED LEGS



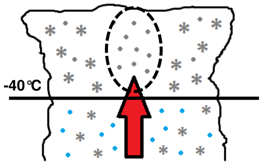


VERTICAL VELOCITY

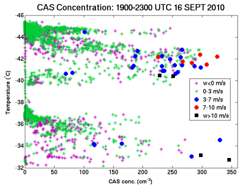
TC lightning requires strong updrafts that support a deep mixed phase region where charge separation can occur (Black & Hallett 1999). Although the majority of inner core vertical velocities in Karl were between ± 2 m s^{-1}, the electrified inner core regions had much stronger updrafts reaching 20 m s^{-1}.



CLOUD MICROPHYSICS



The non-inductive charging mechanism requires graupel and ice particle collisions in the presence of supercooled water. Unfortunately, no direct supercooled water data were collected at flight altitude by the DC-8.

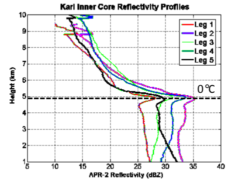


(0.35-50 µm particles)

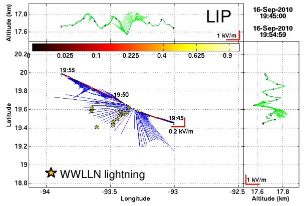
However, strong updrafts were often associated with high concentrations of small, recently frozen ice particles (circled, top) (Heymsfield et al. 2006). The presence of recently frozen, homogeneously nucleated ice particles within strong updrafts (bottom) suggests that supercooled water was present below the aircraft.

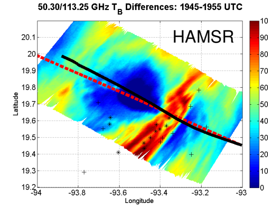
VERTICAL REFLECTIVITY PROFILES

The electrified passes through Karl (legs 2 and 4) had higher reflectivities in the lower troposphere and the mixed phase region. This indicates liquid and ice particles were being lofted high above the freezing level, producing an environment conducive for storm electrification.

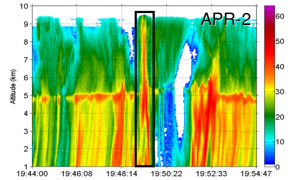


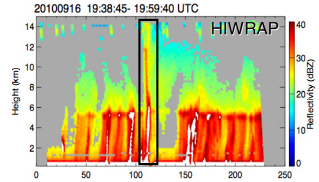
ELECTRIFIED CASE: LEG 2

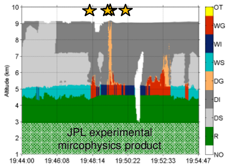


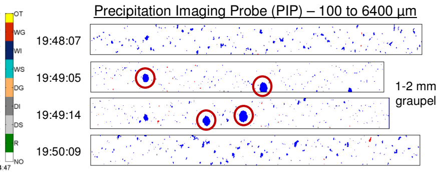


Numerous lightning flashes were recorded within the SE eyewall of Karl during leg 2 (see above). The enhanced reflectivity aloft sampled by APR-2 and HIWRAP (below) indicates a deep mixed phase region that supports charge separation, while the cloud microphysics (bottom) show large graupel collocated with smaller, recently frozen ice particles.









CONCLUSIONS

This study capitalized on the unique opportunity provided by GRIP to synthesize multiple datasets and analyze the physical properties of an electrified TC undergoing rapid intensification.

Electrified regions within Karl were associated with:

- Strong updrafts (w >10 m s^{-1})
- High concentrations of small ice particles (suggest presence of supercooled water below aircraft altitude)
- Deep mixed phase layer indicated by enhanced reflectivity aloft
- Collocated graupel and recently frozen ice particles at 10-11 km

ACKNOWLEDGEMENTS

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